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RECREATIONAL LAKES PROGRAM

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THE
ONTARIO WATER RESOURCES COMMISSION
REPORT
ON WATER QUALITY
IN
CHARLESTON LAKE
1971

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SUMMARY

A study to evaluate the status of water quality in Charleston Lake was carried out during the summer of 1971.

Charleston Lake lies in the physiographic region known as the Frontenac Axis which, as part of the Precambrian Shield, is characterized by moderate to steep topography, poor local drainage and shallow overburden covering Precambrian bedrock. The soil around the lake is generally a sandy loam dominated with rock outcroppings. Both the nature of the soil and topography surrounding this lake can be considered as unsuitable for cottage development utilizing standard sub-surface septic tank systems.

A well-defined thermocline or zone of rapid temperature decline was observed between the warm upper waters (epilimnion) and the cool bottom strata (hypolimnion) during the summer and early fall. During these periods slightly depressed deep-water concentrations of dissolved oxygen and elevated carbon dioxide levels resulting from the decomposition of organic matter were observed. In general, dissolved oxygen concentrations in the hypolimnion were sufficient to maintain cold water species of fish such as lake trout.

The water is relatively hard but has no unusual mineral characteristics. In general the surface waters were characterized by higher pH levels than the bottom strata. Occasionally, pH values in the upper layers exceeded the criteria for public water supplies. These high pH values could cause eye irritation to swimmers.

The Kjeldahl nitrogen and total phosphorus concentrations were generally low and would not be expected to support nuisance levels of algae.

There were high concentrations of phosphorus in the bottom waters at two stations but supporting data was insufficient to substantiate a case of nutrient recycling from the lake sediments.

Algal levels as measured by chlorophyll a concentrations were low during the three surveys, with the exception of moderately high values on May 21, 1971. The algal densities recorded would not be expected to interfere with water oriented recreational activities or diminish the aesthetic quality of the water. In view of the generally low nutrient and chlorophyll concentrations, every effort should be made to protect the existing quality of the water by preventing any direct flow or leachate from domestic waste disposal systems or other potential sources of pollution from gaining access to Charleston Lake.

Charleston Lake had good bacteriological water quality and was generally well within the OWRC recreational use criteria during all three surveys.

INTRODUCTION

Maintenance of good water quality in recreational lakes in the Province of Ontario is of vital concern to the Ontario Ministry of the Environment and other governmental agencies involved in tourism and the control and management of shoreline development of cottages and resorts. In 1970 an interdepartmental program was established to survey a number of recreational lakes in order to detect and correct sources of water pollution and ensure that our lakes would be well managed to protect water quality. The Ontario Department of Health, whose jurisdiction in this program was transferred to the Ministry of the Environment in December 1971, would carry out on-shore inspection and correction of faulty private waste disposal systems, whereas the Ontario Water Resources Commission (now within the Ministry of the Environment) would evaluate the existing quality of the respective lakes.

Recreational lakes are subjected to two major types of water quality impairment; bacteriological contamination and excessive growths of algae and aquatic weeds (eutrophication). The two problems may result from a common source of wastes but the consequences of each are quite different. Bacteriological contamination by raw or inadequately treated sewage poses an immediate public health hazard if the water is used for bathing. In order for this to occur, raw wastes or septic tank effluents must gain entry to the lake although it may not be obvious upon visual inspection of the site. It must be noted that no surface water is considered safe for human consumption without prior treatment including disinfection. The algae and weed growths impair aesthetic values and recreational use of a lake but seldom pose a health hazard. There are nutrient sources other than sewage wastes which do not create serious bacterial hazards but do support nuisance plant growths such as agricultural fertilizer losses and normal nutrient runoff from forest and field.

In line with its responsibility of evaluating the status of water quality in recreational lakes, the Ontario Water Resources Commission undertook a study on Charleston Lake in the summer of 1971. Two 5-day sampling surveys were conducted on Charleston Lake; in spring from May 21 to 25 and in mid-summer from July 15 to 19. A third survey was conducted on the lake in early fall from September 18 to 20. The scope of the surveys included the assessment of bacteriological, physical, chemical and biological conditions.

In addition to the results obtained from these studies, information from other governmental agencies has been incorporated in this report which is the Ontario Water Resources Commission's contribution to the Interdepartmental Task Force Report which will deal with the overall cottage pollution program in Ontario.

AREA DESCRIPTION

Geography and Topography

Charleston Lake is located in the Townships of the Rear of Leeds and Lansdowne, the Front of Escott and the Rear of Young and Escott, in the County of Leeds. The lake is approximately 8 kilometers (5 miles) southwest of the Village of Athens on Highway 42.

Charleston Lake lies in the Frontenac Axis which is a narrow neck of Precambrian bedrock that physically links the Laurentian Shield to the Adirondacks of New York State. The lake lies in three types of Precambrian bedrock. The first type, which involves the north and west shores and most of the islands, is a precambrian crystalline limestone. The second encompasses the south shore and consists of gneisses and schists. The third type which underlies the east shore consists of granite and syenite.

There are two small areas at the north end of the lake with shallow arable soil. One area lies at the head of Webster Bay and belongs to the Tennyson soil type which is a slightly calcareous, stony sandy loam characterized by good drainage. The other area is at the site of the community of Charleston. This soil type is Farmington loam which is a well-drained, shallow, loamy till. The remainder of the shoreline varies from bare rock to small areas of Monteagle sandy loam or Tweed sandy loam soil complexes. The Monteagle sandy loam soils are composed of a very stony, glacial till derived chiefly from the local granitic rocks. The topography in this area is irregular and hilly with numerous outcroppings of bedrock. The depressions are generally marshy or filled with organic sediments. The Tweed sandy loam is bedrock-controlled with medium to steep slopes. The soil is derived from the weathered underlying crystalline bedrock and is generally well drained. In most instances, the soil cover is less than the five feet required by the Ministry of the Environment for the installation of standard subsurface septic tank systems. The shoreline is generally sharply sloping and has a mixed forest dominated by white pine and maple. The slope of the lake-bottom near the shore generally corresponds to the immediate shoreline features.

Charleston Lake is typical of most lakes lying in the Precambrian Shield having a very irregular shape which reflects the nature of the topography of the region.

The lake has a water surface area of 25 square kilometers (6,200 acres) and an irregular shoreline length of 151 kilometers (94 miles). The maximum recorded depth in the lake is 93 meters (302 feet).

Climate Range

The mean annual temperature for the Charleston Lake area is 6°C (43°F). The mean daily temperature in January is -9°C (16°F) and in July is 21°C (69°F). The mean annual precipitation is 86 centimeters (34 inches) with 38 centimeters (15 inches) falling in the period from May to September. According to meteorological reports the area enjoys over 200 days with no measurable precipitation. The summer climate is conducive to most recreational activities and the winter with its abundance of snow provides for participation in most winter sports.

Water Movement

The Charleston Lake drainage basin, approximately 260 square kilometers (100 square miles) in area, flows into the St. Lawrence River via the Gananoque River.

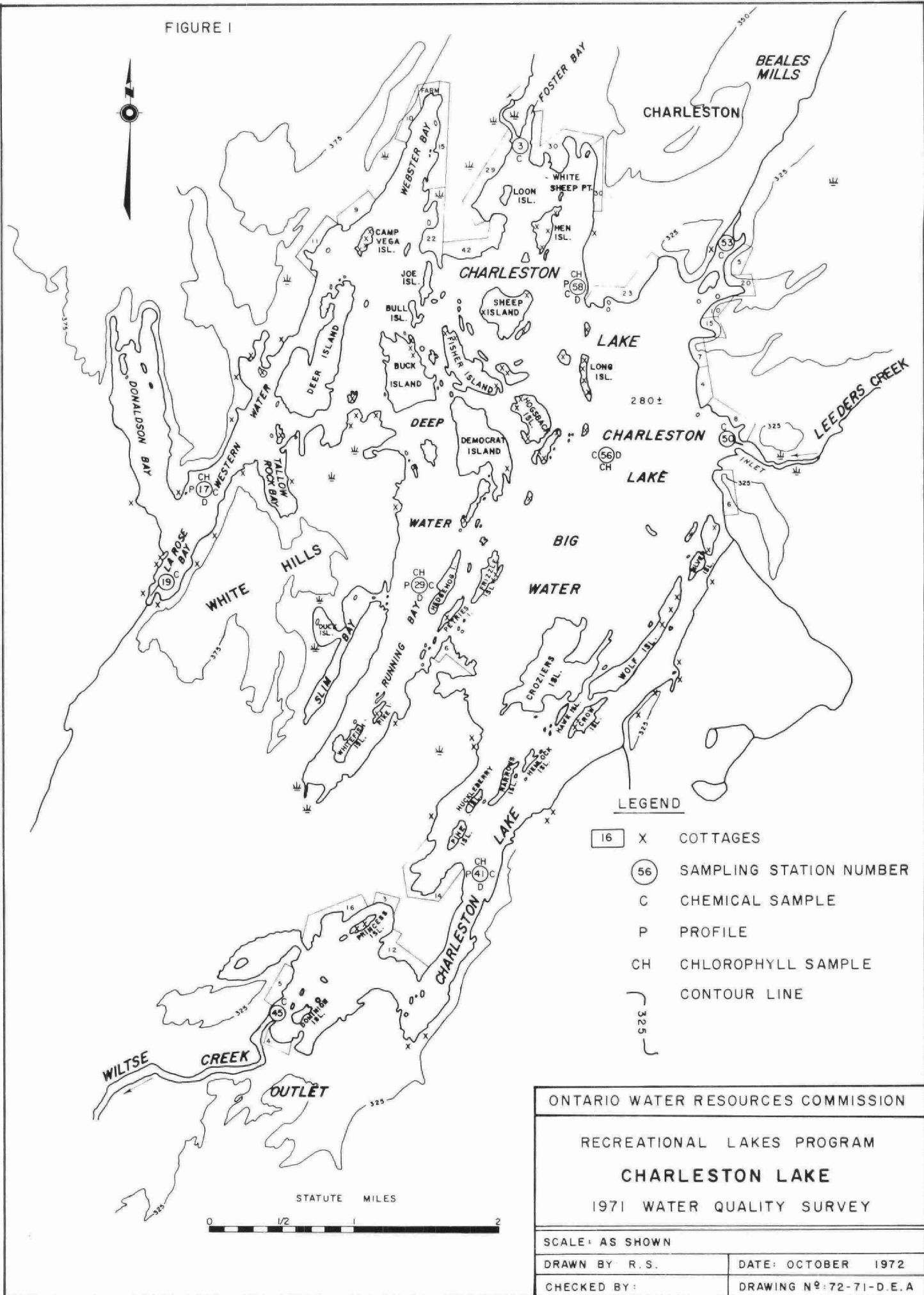
There are seven inlets, well-distributed geographically around the Lake. Five of these inlets have negligible flows and are thus considered seasonal streams. The two permanent inlets are Bailes Creek which drains Wiltse and Loyada lakes, and Leaders Creek which drains Graham, Centre and Temperance Lakes. Both of these inlets have flows which are less than 28 liters per second (1 cubic foot per second).

Wiltse creek near the community of Outlet, controls the lake level. The dam is owned and operated by the Gananoque Hydro Company.

Shoreline Development

Charleston Lake has a number of stretches of well-developed shoreline with a total of approximately 550 cottages. The majority of cottage development is along the north shore and the northern part of the east shore (Figure 1).

FIGURE 1



ONTARIO WATER RESOURCES COMMISSION

RECREATIONAL LAKES PROGRAM

CHARLESTON LAKE

1971 WATER QUALITY SURVEY

SCALE: AS SHOWN

DRAWN BY R.S.

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The community of Charleston has three marinas and two general stores which serve the local residents as well as the majority of cottagers. The cottages in the southern end of the lake are served by a marina and general store at the community of Outlet.

Water Usage

The majority of the cottagers use the lake as their source of domestic water supply. The lake supports recreational water sports such as fishing, boating, water skiing and swimming. According to information available from the Ministry of Natural Resources, the most common game fish in the lake are lake trout, northern pike, smallmouth and largemouth bass. Fourteen other species of fish varying from yellow perch to the american eel are also present.

Waste and Refuse Disposal

There are two solid waste disposal sites serving the communities of Lyndhurst and Charleston within the immediate area of the lake. The Charleston site is approximately 1.2 kilometers (0.75 miles) north of the Hamlet of Charleston, while the Lyndhurst site is approximately 3.2 kilometers (2.0 miles) west of Donaldson Bay. There have been no reports of water pollution problems associated with these sites. There are no effluent producing communal or municipal sewage treatment facilities located in the watershed of this lake. The Hamlets of Athens, Charleston, Lyndhurst and Outlet are serviced by individual domestic waste disposal systems.

FIELD AND LABORATORY METHODS

Physical, Chemical and Biological Field Methods

Water quality surveys were conducted on Charleston Lake from May 21 to 25, from July 16 to 20 and from September 18 to 21. Five near-shore stations (3, 45, 47, 50 and 53) as well as four mid-lake stations (17, 29 41 and 58) were selected for physical, chemical and/or biological sampling (Figure 1). Near-shore stations were adjacent to inlets and outlets.

Dissolved oxygen and temperature profiles were determined daily in the field using a combination dissolved oxygen-telethermometer unit. Total alkalinity and free carbon dioxide were measured daily titrimetrically and pH was measured with a portable pH meter. Daily chlorophyll samples were collected in a 32-ounce bottle, at each mid-lake station, utilizing a composite sampler lowered through the euphotic zone (2X Secchi disc) and immediately preserved with 10-15 drops of a 2% MgCO_3 suspension.

At least once per survey, a 32-ounce sample for hardness, alkalinity, chloride, total phosphorus, total Kjeldahl nitrogen, iron and conductivity was collected at mid-lake stations as well as at the major inlets and outlets.

The mid-lake stations were sampled using a composite sampler through the euphotic zone. At inlets and outlets, samples were collected from 1 meter of depth using a Kemmerer sampler.

At each mid-lake station one sample for total phosphorus, total Kjeldahl nitrogen and iron was obtained by means of a Kemmerer sampler from a depth of 1 meter above the bottom during the July survey.

Physical, Chemical and Biological Laboratory Methods

All analyses were carried out using routine OWRC methods based on Standard Methods 13th Edition.

Iron was measured after the sample had been digested with acid to dissolve all forms of iron present.

Kjeldahl nitrogen and total phosphorus were determined after the sample was digested with acid and an oxidizing agent to destroy organic matter.

For chlorophyll determinations, 1 liter samples were filtered through a 1.2 μ membrane filter which was then extracted with 90% acetone for 24 hours. Absorbance of the extract was determined at wavelengths 600 to 750 m μ using a Unicam SP1800 ultra violet spectrophotometer. The concentrations of chlorophyll a were calculated using the equation given by Richards and Thompson (1952).

Bacteriological Field and Laboratory Methods

Five-day intensive bacteriological surveys were completed in May and July and a three-day survey was completed in September on Charleston Lake. In May and July, 58 surface samples were taken daily as well as four depth samples at Stations 17D, 29D, 56D and 58D. In September, 49 samples were taken daily, including depth samples at Stations 17D, 41D and 56D. Stations 6, 12, 15, 20, 21, 23, 32, 38, 43, 49, 57 and 58 were not sampled in September.

Surface samples were collected at a depth of one meter below the surface using sterile, autoclavable polycarbonate 250 ml bottles. Depth samples were collected one meter above the bottom using a modified "piggy back" sampler and sterile 237 ml evacuated rubber air syringes.

All samples were stored on ice and delivered to the mobile laboratory within two to six hours and analyzed for total coliforms, fecal coliforms and fecal streptococcus using the membrane filtration technique (MF) (Standard Methods, 13th Edition) except that m-Endo Agar LES (Difco) was used for total coliform and MacConkey membrane broth (Oxoid) was used for fecal coliform determinations. The total coliforms (TC), fecal coliforms (FC) and fecal streptococcus (FS) were used as "indicators" of fecal pollution. The "indicators" are the normal flora of the large intestine, and are present in large numbers in the feces of man and animals. When water is polluted with fecal material, there is a potential danger that pathogens or disease causing microorganisms may also be present.

The coliform group is defined, according to Standard Methods, 13th Edition, as "all of the aerobic and facultative anaerobic, gram-negative, non-sporeforming

rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C and, or "all organisms which produce a colony with a golden-green metallic sheen within 24 hours of incubation" using the MF technique. This definition includes, in addition to the intestinal forms of the Escherichia coli group, closely related bacteria of the genera Citrobacter and Enterobacter. The Enterobacter - Citrobacter groups are common in soil, but are also recovered in feces in small numbers and their presence in water may indicate soil runoff or, more important, less recent fecal pollution since these organisms tend to survive longer in water than do members of the Escherichia group, and even to multiply when suitable environmental conditions exist. A more specific test for coliforms of intestinal origin is the fecal coliform test, with incubation of the organisms at 44.5°C. Though by no means completely selective for Escherichia coli, this test has proved useful as an indicator of recent fecal pollution.

Fecal streptococci (or enterococci) are also valuable indicators of recent fecal pollution. These organisms are large, ovoid, gram-positive bacteria, occurring in chains. They are normal inhabitants of the large intestine of man and animals, and they generally do not multiply outside the body. In waters polluted with fecal material, fecal streptococci are usually found along with coliform bacteria, but in smaller numbers, although in some waters they may be found alone. Their presence, along with coliforms, indicates that at least a portion of the coliforms in the sample are of fecal origin.

Bacteriological Statistical Methods

Fluctuations in bacterial concentrations due to changing environmental conditions require that a great number of samples be taken to arrive at a mean value which is representative of a specific sample location or sampling area. The most appropriate mean for bacterial levels and this type of data is the geometric mean. The vast quantities of bacteriological data generated from these samples necessitated the development of additional statistical methods to summarize the mean results into a more concise presentation. The statistical methods used are based on the analysis of variance. The stations on the lake

can be grouped, by this method, into areas or groups of stations within the same statistical bacterial level, without the bias normally associated with manual interpretation.

The analysis of variance is particularly effective where bacterial concentrations vary slightly throughout the lake. Areas or stations with slight differences in bacterial concentrations may be isolated. Areas or stations with statistically higher bacterial numbers reliably indicate an input.

The results from all the analyses were organized as replicates representing the stations during the survey period. All data were transformed to logarithms (base 10) and all further analyses were done using these transformed data. A geometric mean (the antilogarithm of the average of the logarithm) was calculated on each station and for each parameter. The validity of the analyses of variance program (ANOVA-CRE; Burger, 1972), was based on the assumptions that the variances of all the stations were similar (Bartlett's test of Homogeneity) and that the data were normally distributed.

Both of these assumptions were checked on Charleston Lake. The Bartlett's test was found to be non-significant and the data followed a normal distribution, hence the analysis of variance (F-test, Sokal, 1969) was calculated on all stations.

If the F was significant, then the multiple-t test was used to help determine the stations which should be deleted from the overall group to yield a homogeneous group of stations. The withdrawn stations were regrouped with respect to geographic proximity and similar means. The calculations on all groups were repeated using the analysis of variance program until each discrete group was homogeneous. The homogeneous groups that were geographically isolated were compared by means of the Student-t test (using the log GM and S.E.) which indicated the statistical difference between these groups. The Student-t test was also used to compare the grouped bacteriological data from the three surveys.

DISCUSSION OF RESULTS

Temperature and Dissolved Oxygen

In July a well-defined thermocline or zone of rapid temperature decline was apparent between 8 and 10m (Figure 2) at Station 41. This temperature zone serves as a physical barrier to mixing between the warm upper waters (epilimnion) and the cool bottom waters (hypolimnion). Oxygen concentrations in the epilimnion ranged from 7.7 to 11.0 mg/l throughout the lake. Deep water oxygen depletions were not observed and values were generally above the 6.0 mg/l stated in the OWRC criteria for the protection of cold water organisms.

Thermal stratification, was again observed during the September survey (Figure 3). Through the thermocline, dissolved oxygen concentrations declined from 11.1 mg/l at 7m to 6.2 mg/l at 12m. In the cool bottom waters, dissolved oxygen concentrations ranged from a high of 6.5 mg/l to a low of 2.5 mg/l at 15m. Oxygen concentrations immediately above the sediment were lower than those immediately beneath the thermocline as a result of bacterial oxidation of organic matter, biological respiration and chemical oxidation. The presence of dissolved oxygen in the bottom waters was evidence that algae and/or aquatic plant production in the surface waters of the lake were not sufficient to utilize the lake's entire deep water oxygen resource following settling and decomposing. In general, dissolved oxygen concentrations in the hypolimnion were sufficient to maintain cold-water species of fish such as lake trout.

pH, Free Carbon Dioxide and Total Alkalinity

Mean surface pH values for the lake were 8.1, 8.7 and 8.0 for the May, July and September surveys respectively. The pH was generally higher in the surface waters than in the deeper strata. Specifically, on September 20, at Station 41, the values at 1 and 39m were 8.0 and 7.0 respectively. The surface pH during the July survey was in excess of the limit considered to be suitable for most water oriented recreational activities (8.3) (O.W.R.C. 1970). pH values greater than 8.3 may cause eye irritation to swimmers.

Surface water concentrations of carbon dioxide were low throughout the year while bottom water values were considerably higher at mid-lake stations.

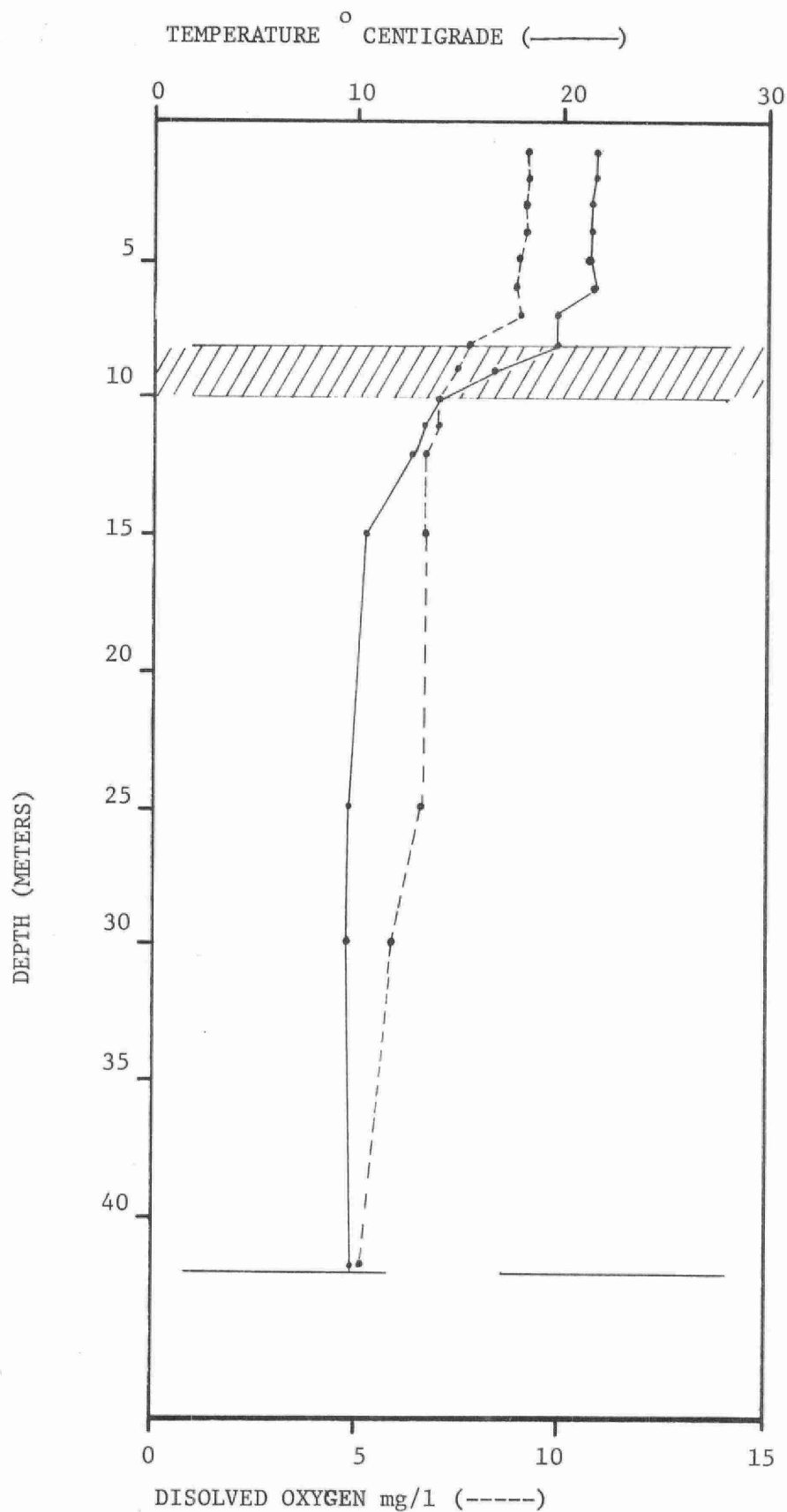


Figure 2: Temperature and dissolved oxygen profiles in Charleston Lake for Station 41 on July 16, 1971. The shaded area approximates the position of the thermocline.

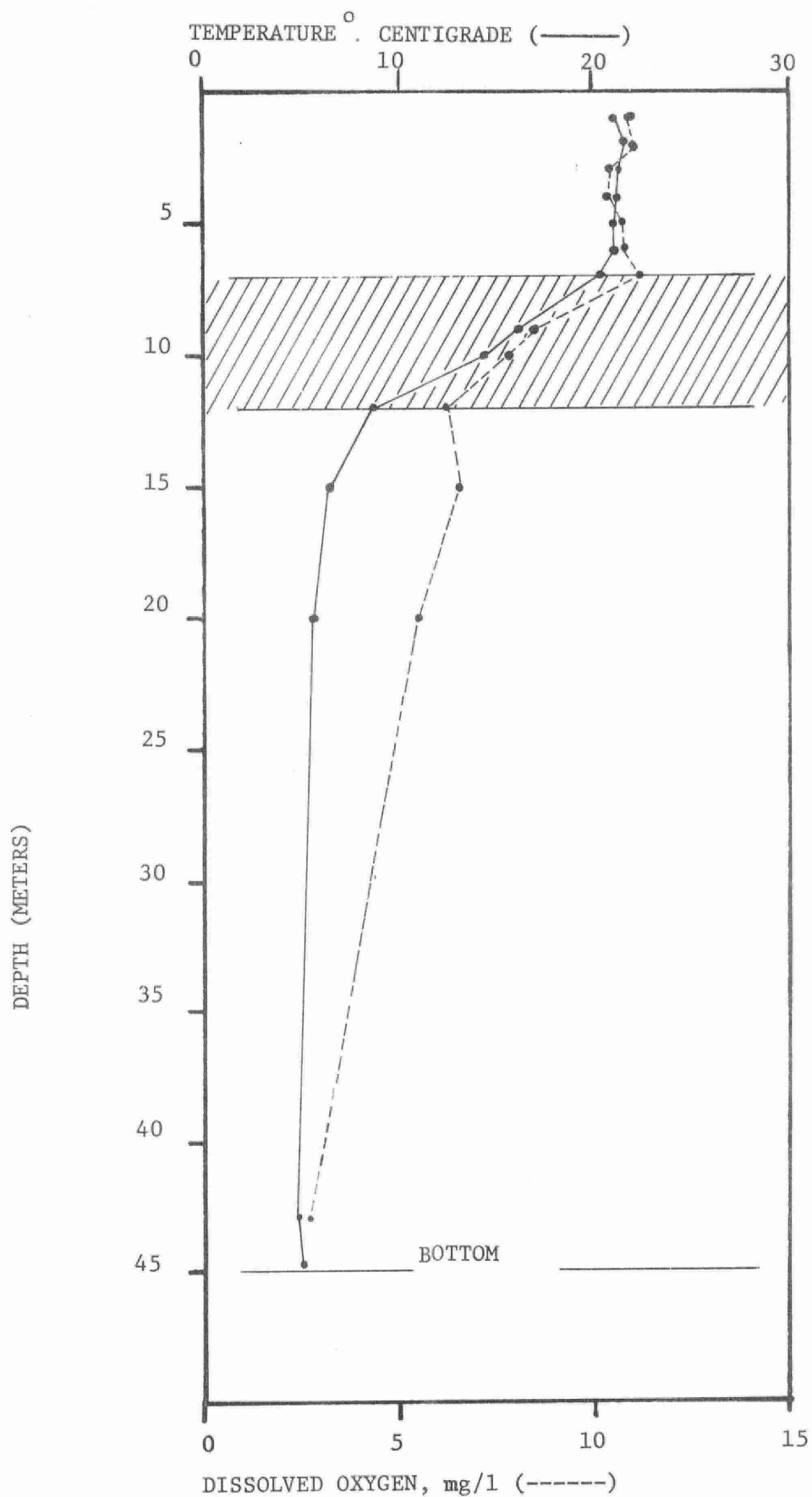


Figure 3: Temperature and dissolved oxygen profiles in Charleston Lake for Station 17 on September 18, 1971. The shaded area approximates the position of the thermocline.

For example, on July 19 at Station 29, concentrations at 1m below the surface and 1m above bottom were 1.9 and 11.2 mg/l respectively. The high, deep-water carbon dioxide values (as well as the above mentioned lower deep-water pH values) were related to conditions of organic decomposition.

Alkalinity values were similar in the surface and bottom waters. For example, at Station 29 on July 19, 1971, the values at 1 and 79m were 107 and 107 mg/l respectively.

Hardness, Chloride, Conductivity and Iron

The hardness, chloride and conductivity data (Table 1) were consistent with each other indicating that no unusual mineral characteristics were present. The water is relatively hard, therefore, detergents containing phosphates are desirable for washing purposes. If such detergents are used by cottagers, every effort should be made to ensure that the waste disposal system does not allow any phosphates to gain access to the lake.

The iron concentrations were generally low as would be expected, however, high concentrations were observed in the bottom waters at Stations 41 and 58 on July 18. These may have been due to recycling from the sediments.

Kjeldahl Nitrogen and Total Phosphorus

The surface water concentrations of Kjeldahl nitrogen and total phosphorus were generally low and would not be expected to support nuisance levels of algae (Table 1). High concentrations of phosphorus were observed in the bottom waters at Stations 41 and 58 on July 18 and again at Station 58 on September 9. Kjeldahl nitrogen concentrations were not as high in these samples as would have been expected if anoxic recycling was taking place. However, the suspicion that nutrient recycling from the sediments may have been occurring is supported by the corresponding high iron values. Mixing of these high levels of phosphorus throughout the epilimnion, as would be expected during the "fall turnover", would augment the supply of phosphorus available for algal growth.

Chlorophyll a

Algal levels as reflected by chlorophyll a concentrations were low during the three surveys, with the exception of moderately high values measured on May 21, 1971 (Table 2). The algal levels measured in Charleston Lake would not be expected to cause a reduction in water oriented recreational activities or diminish the aesthetic quality of the water.

As indicated above, chlorophyll a measures the amount of photosynthetic green pigment in algae while water clarity which is one of the more important parameters used in defining water quality is determined using a Secchi disc. Recently, Brown (1972) has indicated that a near-hyperbolic relationship exists between chlorophyll a concentrations and Secchi disc readings for lakes of Precambrian origin. Figure 4 describes the author's mathematical relationship between chlorophyll a and Secchi disc for 945 sets of data collected from approximately sixty recreational lakes located primarily in Southern Ontario. Points for eutrophic lakes which are characterized by high chlorophyll a concentrations and poor water clarity are situated along the vertical axis of the hyperbola while oligotrophic waters which have low chlorophyll a levels and allow significant light penetration be along the horizontal limb. Mesotrophic lakes would be dispersed about the middle section of the curve. The moderately enriched nature of Charleston Lake is indicated by its close proximity to values computed for Lake Ontario and the Eastern Basin of Lake Erie; two oligotrophic to mesotrophic bodies of water. Significantly, Charleston Lake is well-removed from the Bay of Quinte, The Western Basin of Lake Erie, Riley Lake and Gravenhurst Bay four highly enriched lakes.

Bacteriology

The bacteriological water quality of Charleston Lake was generally good and well-within the OWRC criteria for total body contact recreational use (OWRC, 1970).

During the May survey the overall geometric means for most of the lake, Group A, were 2 TC/100 ml, 1 FC/100 ml and 1 FS/100 ml. Several stations situated in bays and inlets (Stations 1, 3, 7, 19, 30, 31, 32, 42, 47, 50 and 53) had mean TC levels significantly higher than Group A (Table 3, Figure 5), while the mid-lake Stations (36, 39, 44, 56, and 58) were generally lower than Group A (Table 3).

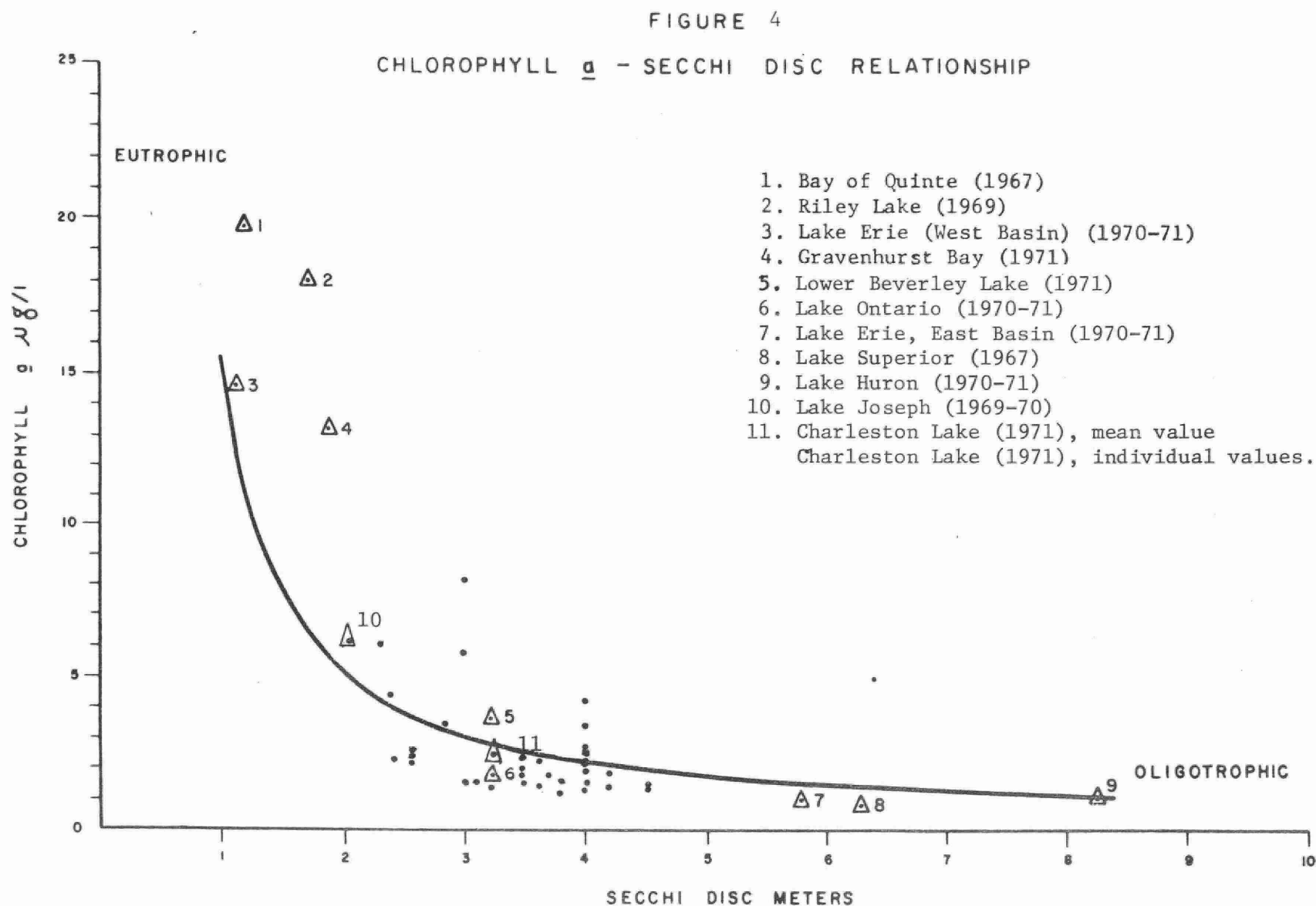
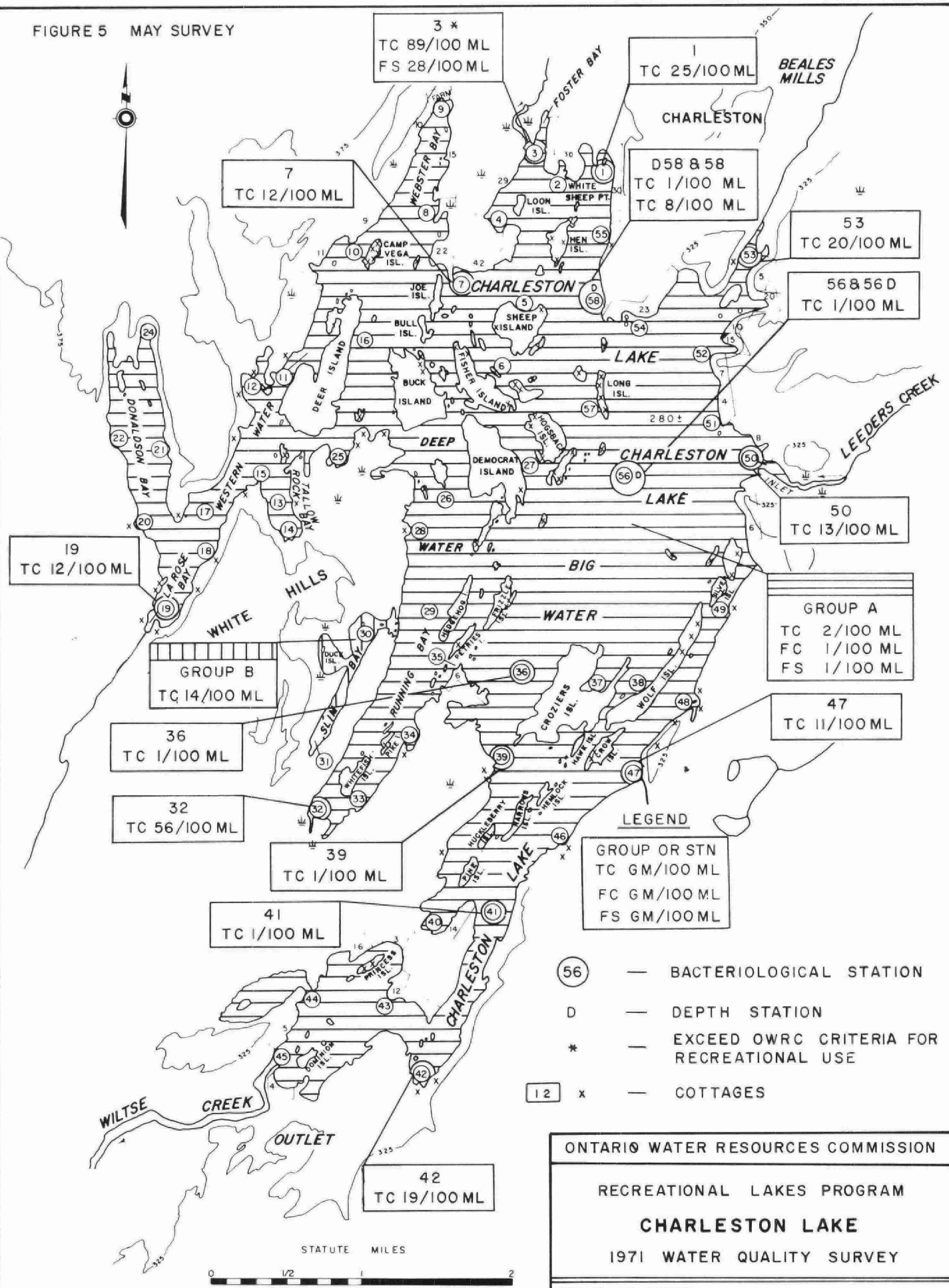


Figure 4: The relationship between chlorophyll a and Secchi disc as determined from the recreational lake survey in 1971 as well as the individual and overall mean values of chlorophyll a - Secchi disc for Charleston Lake. The values for the Great Lakes were added for comparative purposes.

FIGURE 5 MAY SURVEY



ONTARIO WATER RESOURCES COMMISSION

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CHARLESTON LAKE

1971 WATER QUALITY SURVEY

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Station 3, near Charleston was characterized by higher bacterial levels of 89 TC/100 ml and 28 FS/100 ml and exceeded the FS recreational use criteria.

Runoff induced by the rainfall on May 20 (Hartington Climatological station recorded 0.40 inches) caused a general increase in FS daily levels. In several areas these daily levels exceeded 20 FS/100 ml for one or more days.

During the July survey, Group A continued to have low bacterial levels of 11 TC/100 ml, 1 FC/100 ml and 5 FS/100 ml (Tables 3, 4 and 5; Figure 6). The TC levels for Group B and Station 29D were significantly lower than Group A while Station 50 within the influence of a creek with several cottages around it had a higher FC mean of 6/100 ml. The frequent rainfalls during the July survey and the associated runoff caused the FS concentrations to fluctuate. However, there were no corresponding fluctuations apparent in the TC and FC populations.

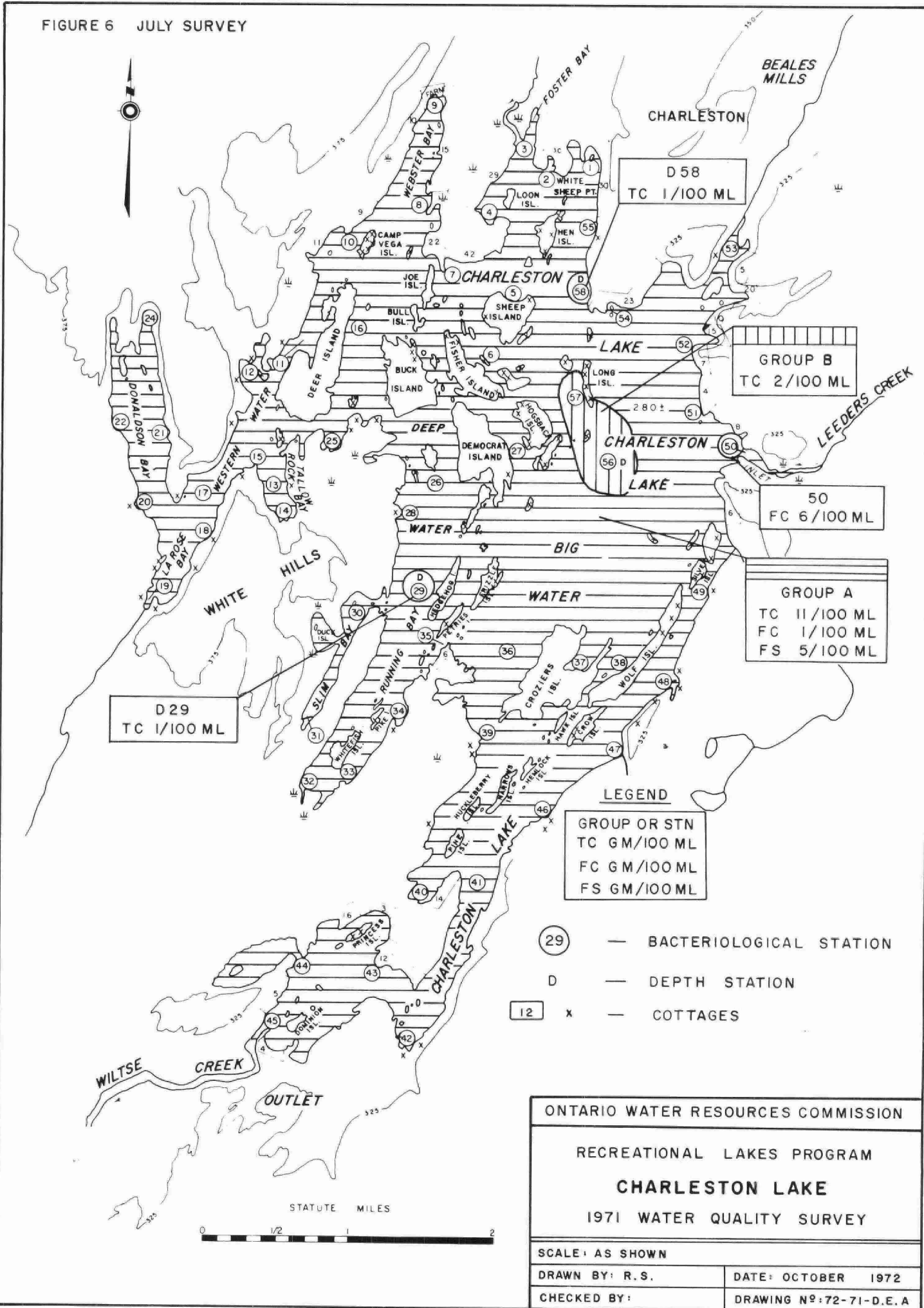
During the September survey the overall geometric mean bacterial levels for Group A were: 57 TC/100 ml, 2 FC/100 ml and 2 FS/100 ml (Tables 3, 4 and 5; Figure 7). Stations 17, 17D and 56D had mean TC levels significantly lower than Group A while Station 56 had a higher FS mean of 5/100 ml.

Station 1 and Station 47 with 194 FC/100 ml and 970 FC/100 ml respectively on the last day of the survey indicated a short term public health hazard after the heavy rainfall on September 19 and 20. Hartington Climatological station recorded 1.03 inches of rainfall for those two days.

Fecal streptococcus fluctuations were most pronounced at Stations 1, 4, 5 and 53. Station 53, with a mean of 131 FS/100 ml exceeded the OWRC recreational use criteria.

Although Charleston Lake generally showed good bacteriological water quality during the three survey periods, no surface water is considered potable without prior treatment including disinfection.

FIGURE 6 JULY SURVEY



ONTARIO WATER RESOURCES COMMISSION

RECREATIONAL LAKES PROGRAM

CHARLESTON LAKE

1971 WATER QUALITY SURVEY

SCALE: AS SHOWN

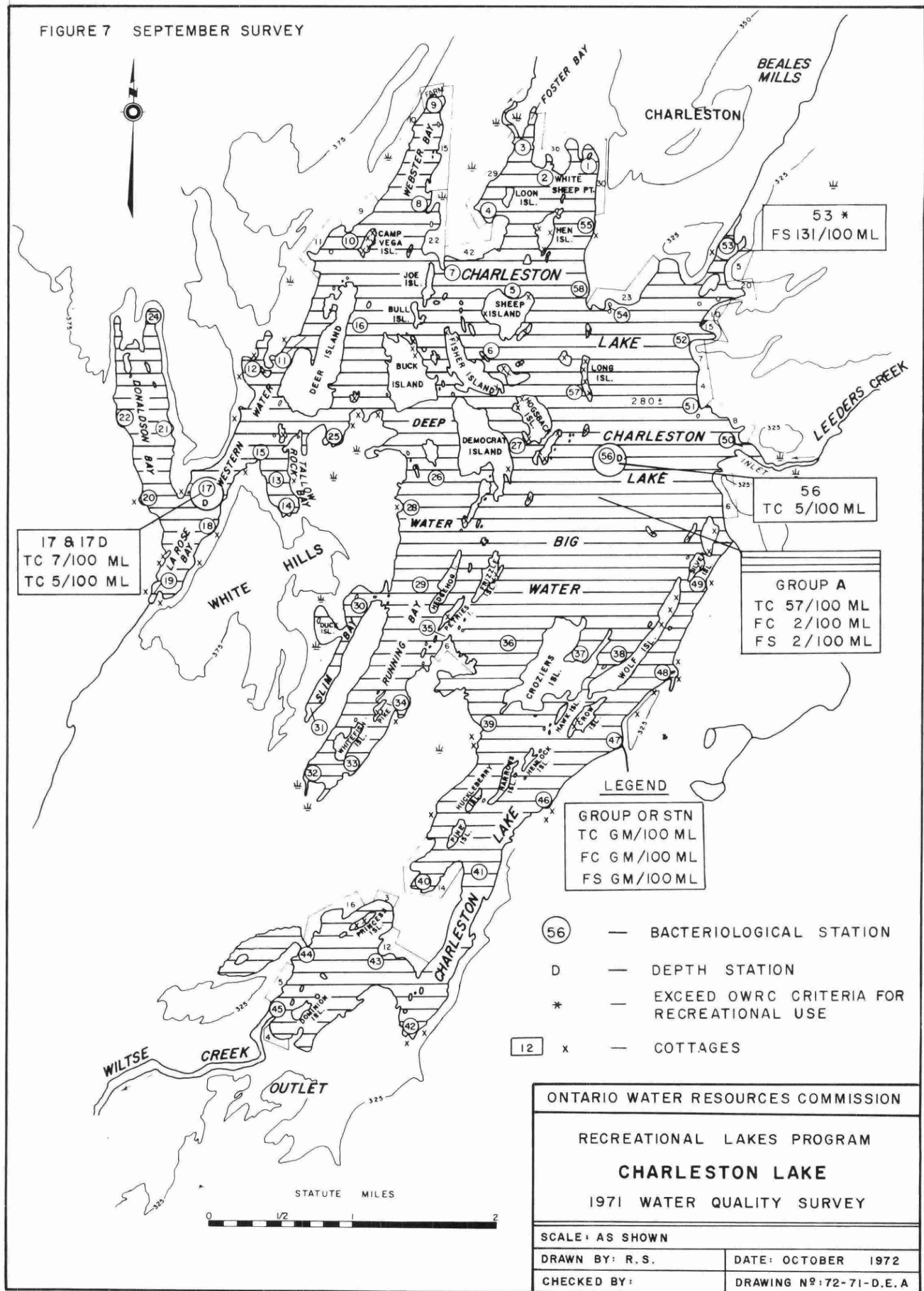
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FIGURE 7 SEPTEMBER SURVEY



EXPLANATION OF TERMS IN BACTERIOLOGICAL TABLES

F	-	the calculated analysis of variance statistic on F ratio.
df	-	degrees of freedom of the F ratio for "between group" and "within group" variation.
F(5%)	-	the F ratio from a statistics table (Rohlf 1969). If the calculated F is greater than the F(5%), a significant difference (SD) occurred between the groups in the analysis. If the F is less than F(5%), no significant difference (NSD) occurred.
log GM	-	the logarithm (base 10) of the geometric mean.
S.E.	-	the standard error of the log GM where $S.E. = \frac{s}{\sqrt{n}} \text{ and } s = \text{standard deviation}$
N	-	the number of values in the mean.
GM	-	the geometric mean of the bacterial level.
t	-	the calculated test of significance or student t-test used to compare stations, groups and a survey. If t for the number of degrees of freedom shown is greater than the critical t value, a significant difference (SD) occurs. SD refers to a significant difference at the .05 level but no significant difference at the .01 level. SD* refers to a significant difference at the .01 level but no significant difference at the .001 level. SD** refers to a significant difference at the .001 level.

Table 1

Iron, Hardness (Hard), Total Phosphorus (P), Kjeldahl Nitrogen (N), Chloride (Cl) and Conductivity (Cond) for Charleston Lake, 1971.

The results are expressed as mg/l except conductivity which is $\mu\text{mhos}/\text{cm}^3$.

Station	Depth	Date	Iron	Hard	P	N	Cl	Cond.
3	1m	21/5	0.10	-	0.029	0.56	-	-
3	1m	25/5	0.10	122	0.025	0.45	4	-
3	1m	19/7	0.05	116	0.016	0.34	5	228
17	4m comp	21/5	0.05	-	0.018	0.48	-	-
17	1m	22/5	0.05	114	0.019	0.47	5	-
17	1m	23/5	0.05	114	0.022	0.40	4	-
17	5m comp	24/5	0.05	114	0.012	0.36	4	-
17	1m	25/5	0.05	112	0.020	0.45	4	-
17	7m comp	18/7	0.05	114	0.020	0.36	5	224
17	41m	18/7	0.15	-	0.060	0.52	-	-
17	8m comp	20/9	0.05	112	0.018	0.39	5	221
29	8.4m comp	18/7	0.05	114	0.015	0.19	6	228
29	79m	18/7	0.65	-	0.040	0.23	-	-
29	8m comp	20/9	0.05	112	0.026	0.44	5	221
29	60m	20/9	0.05	-	0.032	0.32	-	-
41	1m	21/5	0.05	-	0.012	0.45	-	-
41	1m	22/5	0.05	118	0.014	0.42	4	-
41	1m	23/5	0.05	116	0.019	0.46	5	-
41	1m	24/5	0.05	116	0.018	0.51	5	-
41	1m	25/5	0.05	116	0.023	0.49	4	-
41	7.4m comp	18/7	0.05	116	0.016	0.36	6	227
41	41m	18/7	2.4	-	0.072	0.27	-	-
41	8m comp	20/9	0.05	112	0.016	0.41	4	221
41	39m	20/9	0.05	-	0.020	0.46	-	-

Table 1 (continued)

Station	Depth	Date	Iron	Hard	P	N	Cl	Cond.
45	1m	21/5	0.05	-	0.012	0.45	-	-
45	1m	25/5	0.10	116	0.017	0.46	5	-
45	1m	21/9	0.05	112	0.020	0.50	5	220
47	1m	21/9	0.15	84	0.038	0.29	2	182
50	1m	19/7	0.05	114	0.026	0.35	5	225
50	1m	21/9	0.10	112	0.024	0.75	5	215
53	1m	19/7	0.05	118	0.026	0.43	6	230
53	1m	21/9	0.25	156	0.070	1.0	6	304
58	1m	21/5	0.05	-	0.018	0.50	-	-
58	1m	22/5	0.05	118	0.022	0.46	5	-
58	1m	23/5	0.05	116	0.016	0.42	4	-
58	1m	24/5	0.05	116	0.016	0.43	5	-
58	1m	25/5	0.05	114	0.023	0.45	4	-
58	8.4m comp	18/7	0.05	116	0.016	0.36	6	230
58	25m	18/7	3.0	-	0.094	0.25	-	-
58	8m comp	20/9	0.05	112	0.035	0.45	4	221
58	33m	20/9	0.20	-	0.13	0.41	-	-

Chlorophyll a and Secchi disc values for Charleston Lake, Stations 17, 29, 41 and 58, during 1971.

TABLE 2

DATE	STATION 17		STATION 29		STATION 41		STATION 58	
	CHLOR <u>a</u>	S.D.	CHLOR	S.D.	CHLOR <u>a</u>	S.D.	CHLOR <u>a</u>	S.D.
May 21	6.1 µg/l	2.3 m	- µg/l	- m	8.1 µg/l	3.0 m	5.9 µg/l	3.0 m
" 22	2.0	2.3	-	-	1.8	2.3	2.2	2.4
" 23	2.2	2.5	-	-	2.6	2.5	2.5	2.5
" 24	3.1	2.6	-	-	3.2	2.5	3.0	2.5
" 25	3.4	2.8	-	-	3.0	2.5	4.4	2.4
July 16	1.6	3.1	1.3	3.8	2.0	3.5	1.3	3.2
" 17	1.8	3.5	1.6	4.5	1.5	3.5	-	-
" 18	1.1	3.8	1.6	3.0	2.9	3.7	1.9	4.2
" 19	1.5	3.8	-	-	3.4	3.5	1.4	4.2
" 20	-	-	-	-	-	-	2.4	3.6
September 18	1.5	4.0	1.4	4.5	1.1	4.0	-	-
" 19	-	-	2.1	4.0	2.3	4.0	2.0	4.0
" 20	4.1	4.0	3.5	4.0	2.6	4.0	2.5	4.0
Mean	28.4 2.58	34.7 3.5	11.5 1.91	23.8 3.97	54.5 2.88	39.0 3.25	29.5 2.68	36.0 3.27
Overall mean	Chlorophyll <u>a</u> 2.60 µg/l Secchi Disc 3.34 m							

TABLE 3a
CHARLESTON LAKE

ANALYSIS OF VARIANCE SUMMARY OF GROUPS
PARAMETER - TOTAL COLIFORM

Survey	May 21 - 25	July 15 - 19	Sept. 18 - 20
Group	All Stations	All Stations	All Stations
F	3.0242	1.0425	2.0122
df	61,244	61,245	49,100
F _{5%}	1.032	1.032	1.032
	-SD	-SD	-SD

Group	Group A (All stations 1,3,7,19,30-32, 36,39, D41,42,47 50,53,56,D56,58 D58)	Group A (All stations D29,50,D56,57,D58)	Group A (All stations 17,D17,D56)
F	0.7832	1.3256	1.4475
df	44,183	57,228	47,194
F _{5%}	1.37	1.33	1.50
	-NSD	-NSD	-NSD
log G.M.	0.3384	1.0225	1.7538
S.E.	0.0864	0.0412	0.0413
N	228	286	142
G.M.	2	11	57

TABLE 3b

CHARLESTON LAKE

Group	May	July
	Group B (St. 30,31)	Group B (St. 56,D56,57)
F	1.2808	0.7272
df	1.8	2.12
F _{5%}	5.32	3.89
.	-NSD	-NSD
log G.M.	1.1359	0.3172
S.E.	0.0916	0.1363
N	10	15
G.M.	14	2

TABLE 4
CHARLESTON LAKE
ANALYSIS OF VARIANCE SUMMARY OF GROUPS
PARAMETER - FECAL COLIFORM

Survey	May 21 - 25	July 15 - 19	Sept. 18 - 20
Group	All Stations	All Stations	All Stations
F	2.010	0.8964	1.060
df	61,244	52,247	50, 99
F _{5%}	1.32	1.32	1.50
	-SD	-NSD	-NSD

Group	Group A (All stations) (except St.50)	Group A All stations	Group A All stations
F	0.8766	0.8964	1.060
df	61,241	62,247	50, 99
F _{5%}	1.32	1.32	1.50
	-NSD	-NSD	-NSD
log G.M.	0.0149	0.0308	0.3255
S.E.	0.00565	0.0073	0.0029
N	303	310	150
G.M.	1	1	2

TABLE 5
CHARLESTON LAKE
ANALYSIS OF VARIANCE SUMMARY OF GROUPS
PARAMETER - FECAL STREPTOCOCCUS

Survey	May 21 - 25	July 15 - 19	Sept. 18 - 20
Group	All Stations	All Stations	All Stations
F	1.463	0.7520	1.611
df	61,244	62,239	49, 98
F _{5%}	1.32	1.32	1.50
	-SD	-NSD	-SD
Group	Group A (All stations) (except St.3)	Group A All stations	Group A (All stations) (except St.53)
F	1.1272	0.7520	1.0519
df	61,237	62,239	49,101
F _{5%}	1.32	1.32	1.50
	-NSD	-NSD	-NSD
log G.M.	0.1577	0.6567	0.2376
S.E.	0.0252	0.0352	0.0393
N	299	302	151
G.M.	1	5	2

GLOSSARY OF TERMS

ALKALINITY	:The alkalinity of a water sample is a measure of its capacity to neutralize acids. This capacity is due to carbonate, bicarbonate and hydrozide ions and is arbitrarily expressed as if all of the neutralizing capacity was due to calcium carbonate alone.
ANOXIC	:Refers to conditions when no oxygen is present.
BACKGROUND COLONIES	:Background colonies are other lake water bacteria capable of growing on the total coliform plate, in spite of the inherent restrictive conditions.
CHLORIDE	:Chloride is simply a measure of the chloride ion concentration and is not a measure of chlorination.
CHLOROPHYLL <u>a</u>	:A green pigment in plants.
CONDUCTIVITY	:Conductivity is a measure of the waters ability to conduct an electric current and is due to the presence of dissolved salts.
DIATOMS	:Unicellular plants found on all continents and in all types of water where light and nutrients are sufficient to support photosynthesis. They are comprised of two siliceous frustules (cell walls) which have an outer valve (epitheca) fitting over the inner valve (hypotheca) like the lid on a box. The siliceous deposits comprising the frustules vary in regular patterns according to the individual species.
EPILIMNION	:Is the thermally uniform layer of a lake lying above the thermocline. Diagram I.
EUPHOTIC ZONE	:The lighted region that extends vertically from the water surface to the level at which photosynthesis fails to occur due to insufficient light penetration.
EUTROPHIC	:Waters containing advanced nutrient enrichment and characterized by a high rate of organic production.

EUTROPHICATION	:The process of becoming increasingly enriched in nutrients. It refers to the entire complex of changes which accompanies increasing nutrient enrichment. The result is the increased production of dense biological growths such as algae and aquatic weeds which generally degrade water quality and render the lake unsuitable for many recreational activities.
FECAL COLIFORMS (FC)	:Fecal coliforms are bacteria associated with recent fecal pollution from man and animals.
FECAL STREPTOCOCCUS (FS)	:Fecal streptococcus are bacteria associated with fecal pollution from animals and to a lesser extent man.
HARDNESS	:Hardness of water is a measure of the total concentration of calcium and magnesium ions expressed as if all of the ions were calcium carbonate.
HYPOLIMNION	:The uniformly cold and deep layer of a lake lying below the thermocline, when the lake is thermally stratified. Diagram #1
KJELDAHL NITROGEN	:Sum of nitrogen present in the ammonia and organic forms (it does not include nitrite or nitrate).
MESOTROPHIC	:Waters characterized by a moderate nutrient supply and organic production (i.e. midway between eutrophic and oligotrophic).
METALIMNION	:See thermocline.
OLIGOTROPHIC	:Waters containing a small nutrient supply and consequently characterized by a low rate of organic production.
pH	:Is the measure of the hydrogen ion concentration expressed as the negative logarithm of the molar concentration.
PHOSPHORUS (TOTAL)	:Sum of all forms of phosphorus present in the sample.

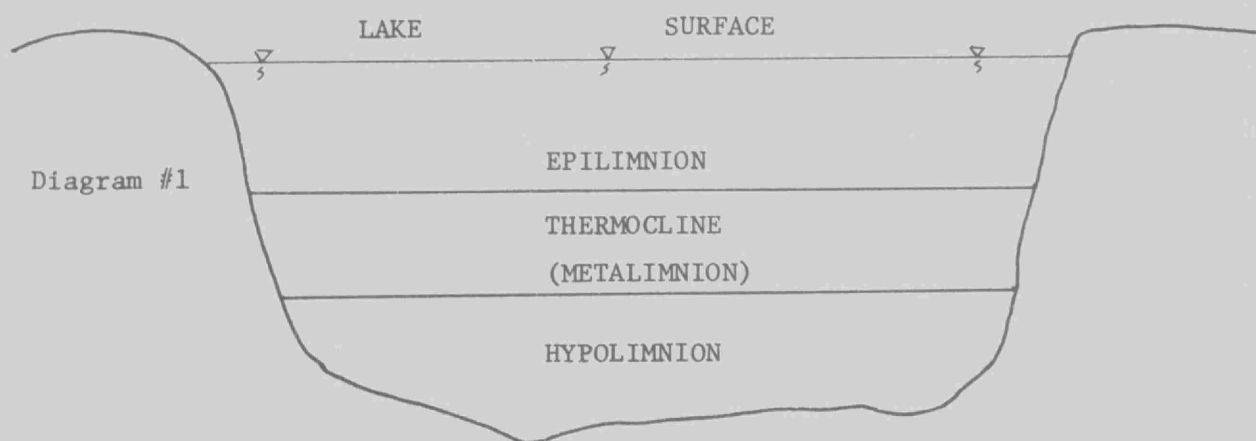
SECCHI DISC

:A circular metal plate, 20 centimeters in diameter, the upper surface of which is divided into four equal quadrants. Two quadrants directly opposite each other are painted black and the intervening ones white. The secchi disc is used to estimate the turbidity of the lake water.

THERMAL STRATIFICATION :During the spring, vertical temperatures in a lake are homogeneous from top to bottom. As summer advances, the surface waters become warmer and less dense than the underlying cooler waters. A strong thermal gradient (Thermocline) occurs giving rise to three distinct water layers. The variation in density between layers retards mixing by wind action and water currents. Diagram #1.

THERMOCLINE (metalimnion)

:The layer of water located between the epilimnion and hypolimnion in which the temperature exhibits a decline equal to or exceeding 1°C increase per meter.



TOTAL COLIFORMS (TC) :Total coliforms are bacteria commonly associated with fecal pollution but may also be present naturally in the environment.

TROPHIC STATUS :Depending upon the degree of nutrient enrichment and resulting biological productivity, lakes are classified into three intergrading types:

TROPHIC STATUS
(continued)

:oligotrophic, mesotrophic and eutrophic.

If the supply of nutrients to an oligotrophic lake is progressively increased, the lake will become more mesotrophic in character and with continued enrichment it will become eutrophic.

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Water used for body contact recreational activities should be free from pathogens including any bacteria, fungi or viruses that may produce enteric disorders or eye, ear, nose, throat and skin infections. Where ingestion is probable, recreational waters can be considered impaired when the coliform, fecal coliform, and/or enterococcus geometric mean density exceeds 1000, 100 and/or 20 per 100 ml respectively, in a series of at least ten samples per month, including samples collected during weekend periods.

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